9-1981

Program Comments

Michael J. Buckley
United States Department of Defense

J. Moyzis
United States Air Force

Program Comments

Abstract
I just want to give you a little history because I think we tend to forget where we started from, not that many years ago, in this technology and what led up to the approach which is described in the film. I think this program really had its origins in the Air Force. 1970 to 1972 was a good period, particularly 1970, when you had the crash of the F111 and a major increase in concern about the safety of aircraft structures. A lot of things changed and, basically, what happened was that there was the recognition that nondestructive evaluation or nondestructive inspection had to change from simply the problem of detection to the problem of measurement in order to incorporate fracture mechanics into life prediction. It changed from a zero-defects philosophY to a damage-tolerant philosophy.

Keywords
Nondestructive Evaluation

Disciplines
Materials Science and Engineering

PROGRAM COMMENTS

M. J. Buckley
Defense Advanced Research Projects Agency
Arlington, Virginia 22205

and

J. Moyzis
Air Force Wright Aeronautical Laboratories
Wright Patterson AFB, Ohio 45433

This is the film which we mentioned last year. It took us a while to get it completed. It is really into management, but it is trying to explain the breadth of work in nondestructive evaluation and its impact. We should have some extra copies of this film available for loan if people are interested in it. We will show the film and make some comments afterwards.

(Film, "Towards a Sound Decision" shown)

I just want to give you a little history because I think we tend to forget where we started from, not that many years ago, in this technology and what led up to the approach which is described in the film. I think this program really had its origins in the Air Force. 1970 to 1972 was a good period, particularly 1970, when you had the crash of the F111 and a major increase in concern about the safety of aircraft structures. A lot of things changed and, basically, what happened was that there was the recognition that nondestructive evaluation or nondestructive inspection had to change from simply the problem of detection to the problem of measurement in order to incorporate fracture mechanics into life prediction. It changed from a zero-defects philosophy to a damage-tolerant philosophy.

At that time there were certainly a large number of techniques available in practice. On the research area you found that almost every program was simply trying to increase the sensitivity of techniques. They were really still pursuing the idea of zero defects. There was no significant university research, at least in any quantity. It was very much people who knew NDE who were working on trying to improve the techniques. There was very limited funding, and this funding was primarily for rather applied problems.

What to do about it led to this program, primarily, and several others to really develop a scientific foundation for understanding the interaction of energy with flaws is the primary initial objective of the program; to develop a new paradigm; that is, a new way of looking at the whole field, a new level of understanding.

There were a series of workshops to identify what were the opportunities, what were the problems, to find people whom we could attract out of other areas to work in this field, and to try to focus basic research. In doing that, for many reasons, we selected ultrasonics as the field in which to work. In this area we had a strong academic base compared to other areas. Its ultimate potential looked behind us, and I think it probably still does for the widest number of things. It is still not a panacea.

I think we found a champion in industry to pull the program together in Don Thompson. This was very important. In fact, it is critical to the whole program of being able to have a core and subcontractors and fit in the pieces in an environment in which the program can be actually managed and not just the money allocated based on need, which has been a problem with a lot of multi-disciplinary programs.

I think the annual open meetings are very important. I think we probably would achieve 50 to 75 percent of the progress if people did not have to get up here and explain their results to their peers. I think having joint support from ARPA and the Air Force has been very important, also. You need the stimulation from the basic side, and you need the pull from the applied side. I think both of those working together have contributed to the success of the program.

But what I really wanted to talk about was how our viewpoint of the field changed. This is sort of the initial model which we had when we started the program. I am speaking simply of the quantitative NDE part. The program had several components, but this was always about two-thirds of the activity. Basically, we said if we are going to get geometrical information about defects, we had to worry about parts, geometry, and transducers. We could either image a defect or go into scattering where we would measure amplitude, phase, and frequency. From the scattering theory we had developed references, we could make comparisons, and then extrapolate or infer what the nature of the defect was.

The program was initially structured something like this. You can see a lot of the people have changed. This is about two-thirds of the program, the basic quantitative NDE, adhesive bonds and composites and strength-related properties; these together were about one-third of the program.

Within about three years, the model had refined itself somewhat, basically realizing that the data inversion was a key item here. Comparison to references was not satisfactory for extracting the data. That changed a lot of the theoretical work. There was still the forward scattering problem being attacked, and the measurement, but increasing emphasis on how do you invert the data. You see much more of that still today. That is a classic problem. At first, I think the theorists were scared by it because it was not an area in which they had been working, but quickly decided this was a rather exciting problem and one from which they could really get a lot.

About the same time we started to conceptually talk about the problem of coupling this technology into life prediction. At this point, it was simply block diagrams. We were still just working really on the measurement side. We said we had to give this to fracture mechanics somehow and make decisions. People were publishing work on the impact of loss functions, on the decision-making process. But we really had not incorporated it too much into the program.

The program structure had changed a little. Primarily, we shifted over to surface flaws as one of the areas, realizing that surface flaws cause a lot of failures. There was no direct effort in that area in the program which also brought in electromagnetic techniques besides ultrasonics. Advanced materials dealt primarily with ceramics, but also included some additional work on composites and adhesive bonds at this point. Then finally, you get to the model which the film talks about in sort of gross terms, which really comes out as the work in ceramics, where you now have a statistical framework in which to view the whole problem.

I think that the point I wanted to make is that in six years our whole thinking about the area has expanded quite a lot. We have refined it. We have put a mathematical framework around it. I think it is illustrative of how a program like this, although it has basically been one program, evolves continually. The areas change. The basic goal was still there, and that was to ensure the safety, the maximum cost effectiveness of components of structures in service. But the technical approach has evolved in time.

Let me show you what the funding looks like. This dotted line is where the program is currently funded through FY 1980. Do not forget that before this program started in this more or less fundamental work, I do not think you could have found $200,000 within DOD, so it was a major increase at that point. It grew rapidly.

ARPA intentionally reduced their funding in the 1979 time period to try to force the other services to get involved in the program. That is something we have not succeeded in yet, but we are going to make a more conscious effort in the next three to six months. This dotted line is what the level of funding would have been just to correct it for inflation for the next four years. So there has been an erosion in the spending power of this program from that period. That is history.

Some of the things that I think we see for the future are kind of exciting, some of them clearly outside of this program: certainly the general inversion is something that people will search for probably for the next 50 years. It is almost impossible, but we will get there closer and closer for more specific cases, and they will have major impact. If we can do something in radiation to by-pass the bulk of accounting statistics, and allow us to use that technique and avoid all the contact problems for small defects, that will be very powerful. There are some things coming along which clearly help in that area.

I think the fatigue life work, which will be mentioned during this program, is a tremdous potential. If we can ever measure residual stresses and particularly the gradient of stresses in materials, we could have a tremendous increase in our ability to predict remaining life. Artificial intelligence in the NDE system is something we have been talking to people about recently: how to marry the artificial intelligence world into the inspection world and effectively be able to clone the best of the experienced inspector with the physics in a system that most anyone can use. If you understand artificial intelligence or its basic premise, you would understand that. If not, we would have to talk about it some more.

In-service NDE and retirement-for-cause you will hear about this morning. I think it is a very exciting area. It is a case where these technologies do have to come together. There are different levels of sophistication that are possible, but it could be the first case of really applying this whole methodology to real hardware systems and use it to make decisions.

That is really all I have to say. It is nice to be here again and I am glad you could all make it. Thank you.

Dr. Joseph Moyzis from the Air Force Materials Lab would like to say a few words.

Joseph Moyzis (AFWAL): I will talk very briefly here, but I would like to bring up a few points that are of interest to the Air Force in our continuing support for this program. The scientific and technical content of this program is very high, and the Air Force has a continuing interest in such work. However, many of the questions that we get, from our constituency are, of course, a little bit different than the questions you get from a strictly technical, basic research point of view.

There is a continuing Air Force interest indicated by the fact that we are going out right now on a three-year extension of this contract, as Mike's money picture showed. There will be funds out in the future years. But the questions I am asked about a program like this -- and undoubtedly the other services will be asking similar questions if they are asked to put money in -- are "What are we going to get out of this?" "How will what you're doing impact our programs?" and that does not mean back in 1990 or 2000 when we are all done. That means what elements of this program that you have underway now can we transition out today or in the near future? What little bits and pieces of this program will fit in other programs we have going? We have had some successes here. We have had some technical possibilities that have appeared which have attracted funding separate from this program. For example, some of the electromagnetic work, the work being done by Bert Auld et al is being transitioned out into a funding line completely separate from this program to investigate the possibilities of using the ferromagnetic eddy current probe on practical Air Force inspection problems.

We also have some other money for transitioning techniques that are proven out in the test bed program. The objective of this money is the construction of a quantitative ultrasonic inspection module, to try to incorporate some of the techniques that are being developed here, whichever ones are applicable, whichever ones we think can be transitioned at the present time, into an actual module that can be linked to a standard ultrasonic unit so that we can really start to do some flaw sizing. We do not have to have four decimal-place accuracy. In many cases, a rough sorting would help. For example, where you have a real inspection probability curve and you want to reject the flaws that are large and ignore the flaws that are small, it would be nice when you receive the flaw signal if you could just sort into large and small. The better you can do that, the more useful these techniques we are developing will become. That sorting capability alone would be of interest.

In that sense, what we are interested in are transition ideas. I would just like to ask the people here, the people directly involved in the program and the people who are not, that when you see opportunities for such transition possibilities, let us hear about them. We would like to hear what you think your technique could do to fill a gap in the state-of-the-art or handle an inspection problem that exists. We have a lot of problems, and we would certainly like to hear your viewpoint on these transition ideas.

Let me make a suggestion as to how you should communicate your thoughts about the use of the output of your work. There is a prime contractor, there is ARPA, there is the Materials Lab. Hopefully, at a later time, other people. When you have an idea, write it up, Xerox it and send it to everyone involved and let them know what your ideas are. That way I think you are going to get the best consideration from the system for what you are doing.

As far as the future of the program is concerned, we look at this as an evolutionary program, and that has been pointed out by Mike too. Over time the people have changed, the emphasis has changed. We see that going on in the future. No matter how the program goes, we do not see a sharp break either in personnel or in content, in this program. For example, from the point of view of the Materials Lab, we would like to see more in eddy current. We sure would like some good ideas in composites NDE that would attack real, material property problems. And hopefully, we are going to hear about some of that later today. But we look for such emphasis changes to be made rationally.

The last thing I want to say, while we are talking quantitative NDE here, and that is very, very important. There is something the Air Force considers even more important. That is reliability. Quantitative NDE is extremely important to us, and we want to develop that capability, but we absolutely have to get increased reliability. We have to be able to find whatever size flaw we want to find essentially all the time. Pushing a technique to greater and greater sensitivity does not give that capability to us unless we can get at the same time a guarantee that the technique will find what it says it will find essentially all the time. And, so, when you do what you do, it is not only a matter of sizing, it is a matter of getting a technique that will do a consistent job: that will read the same thing consistently time after time on the same kind of defect.

I do want to point out that on Wednesday evening, in this room, I am going to have a session at 8:00 o'clock when we are going to discuss one of the prime inspection problems in the Air Force, cracks in multi-layered structures. You are going to hear about another prime problem, retirement-for-cause this morning. But the cracks in multi-layered structures is still with us. We are looking at various techniques in ultrasonics and electromagnetics and we have money available if anybody comes up with some idea to attack that problem, the detection of flaws around holes in multi-layered structures. I have asked people from the contractors who are presently working on this problem to come in and give a very short discussion of what they are doing, and they will be available for discussion afterward until we all get tired and go home. Thank you.